Modeling Mobile Source Air Toxics Hot Spots

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Air Toxics Center

Overview of Presentation

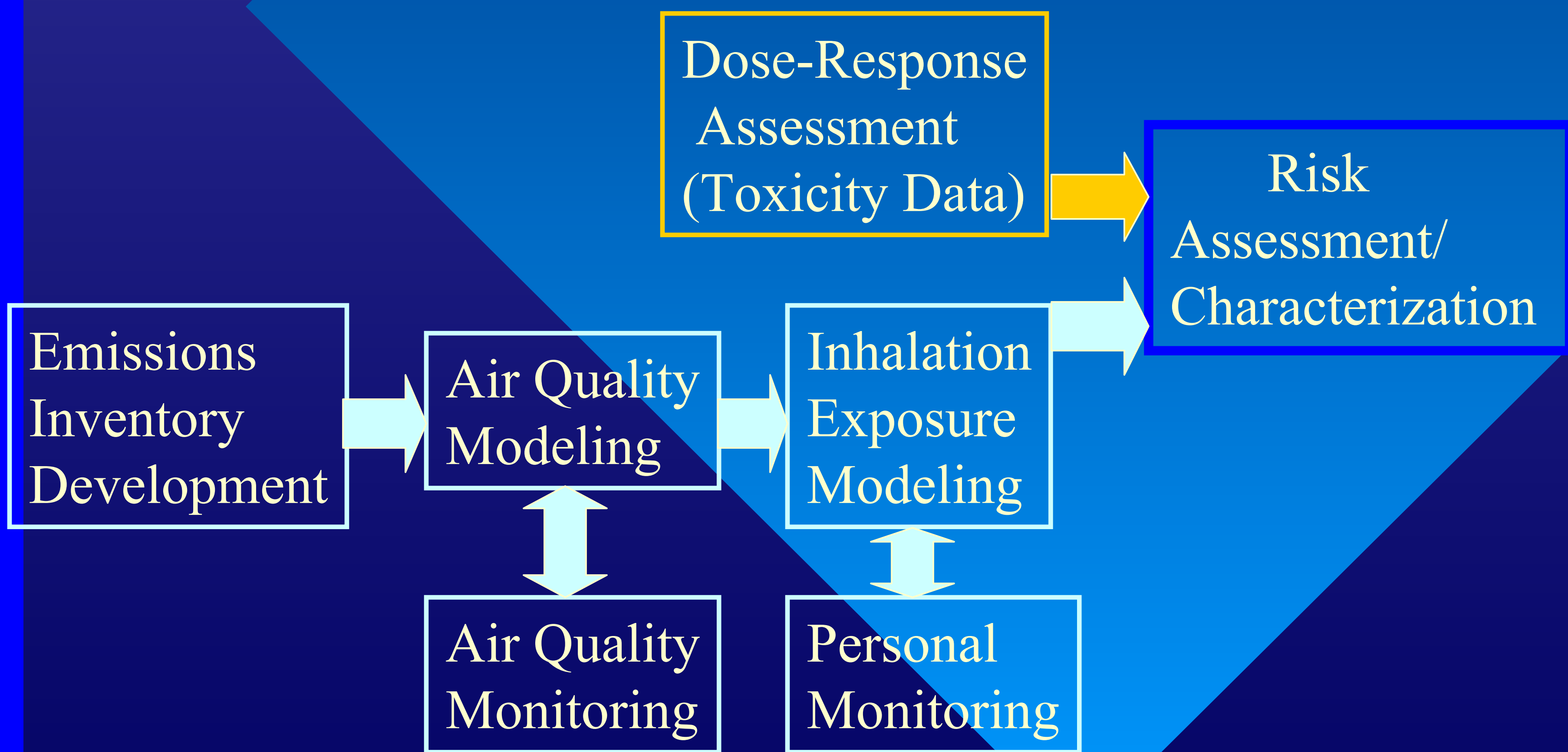
- Introduction to air toxics
- Microscale traffic modeling
- CALINE4 model
- Hands-on demonstration with CL4

EMISSIONS: Mobile Source Air Toxics

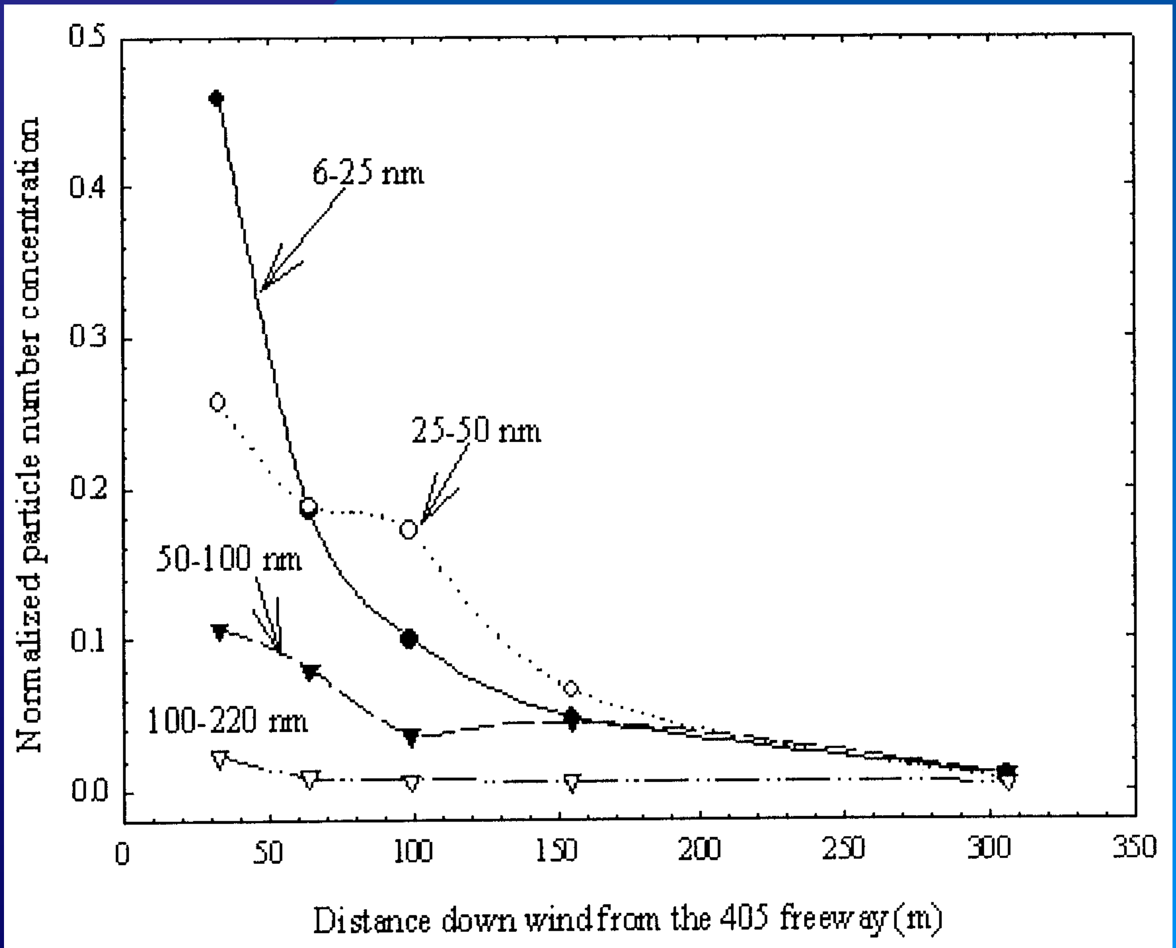
- Acetaldehyde
- Acrolein
- Arsenic Compounds
- Benzene*
- 1,3-Butadiene
- Chromium Compounds
- Dioxins/Furans
- Diesel PM + OG
- Ethylbenzene*
- Formaldehyde
- n-Hexane*
- Lead Compounds
- Manganese Compounds
- Mercury Compounds
- MTBE*
- Naphthalene*
- Nickel Compounds
- POM
- Styrene
- Toluene*
- Xylene*

*Found in evaporative as well as exhaust emissions.

Air Toxics Assessment
(Inhalation)



Why is microscale important?



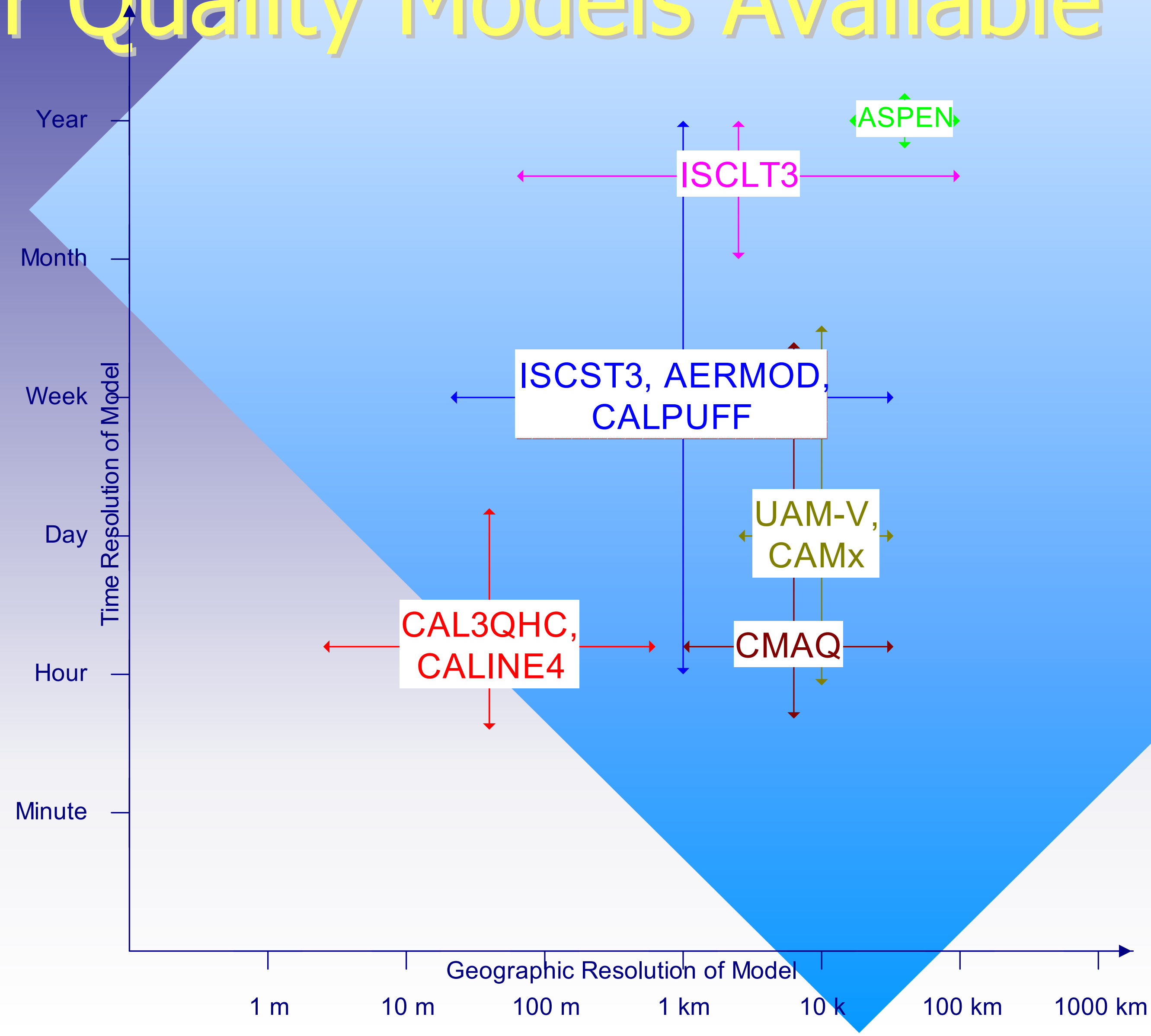
- Courtesy Dane Westerdaal

- Living near busy roads associated with asthma, adverse birth outcomes, and childhood cancer in multiple studies
- A Dutch study also showed that people 55-69 years old who lived near busy roads had 95% greater risk of death from cardiovascular or respiratory causes

Tools for modeling air toxics in air near roadways...

- Emission models
  - MOBILE6.2 - draft emission factor model that provides estimates of 6 toxics
- Air quality (dispersion) models
  - CAL models (CALINE3/4, CAL3QHC/R)
  - HYROAD (Hybrid Road and Intersection Model)
  - Other models (ISC)

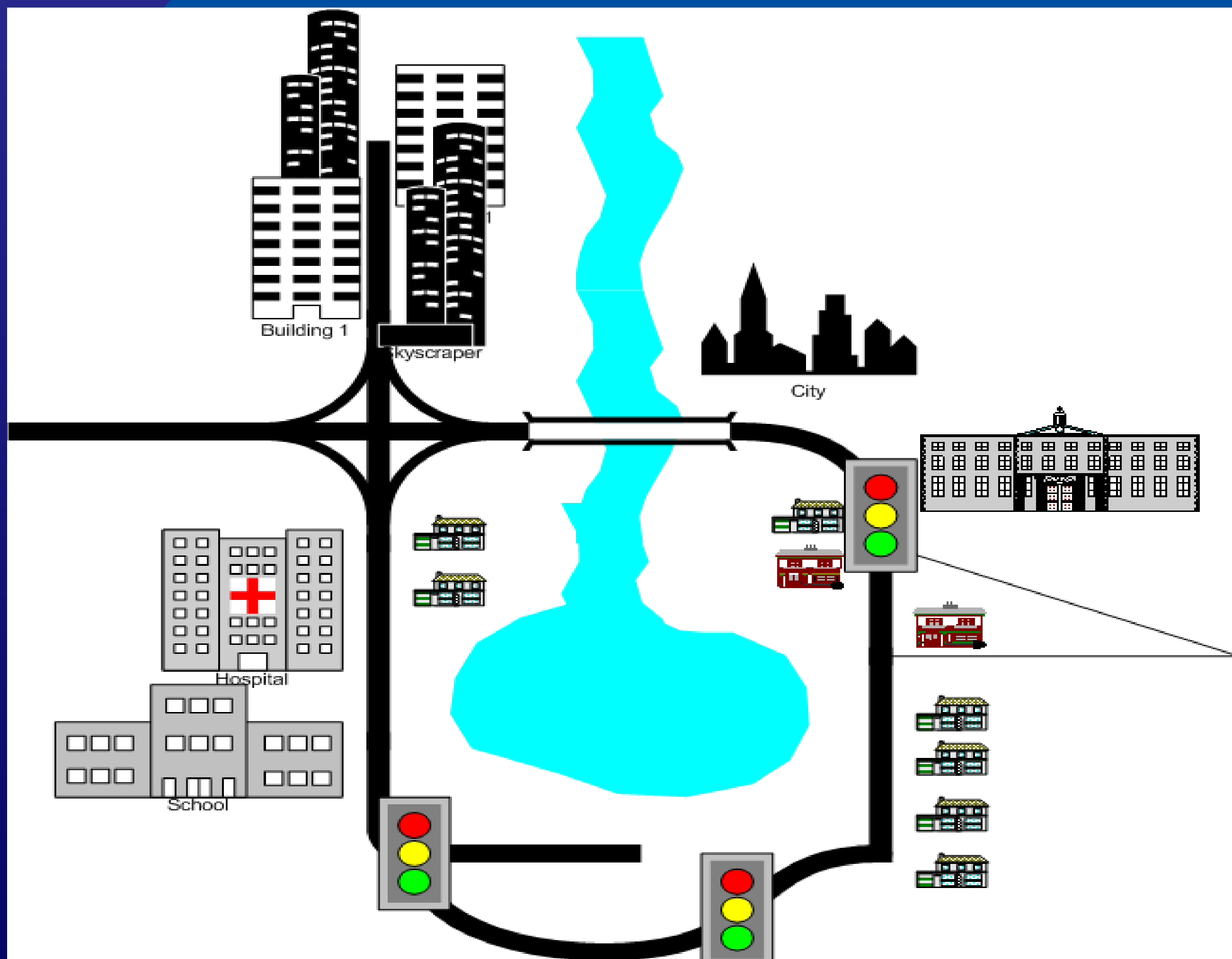
Air Quality Models Available



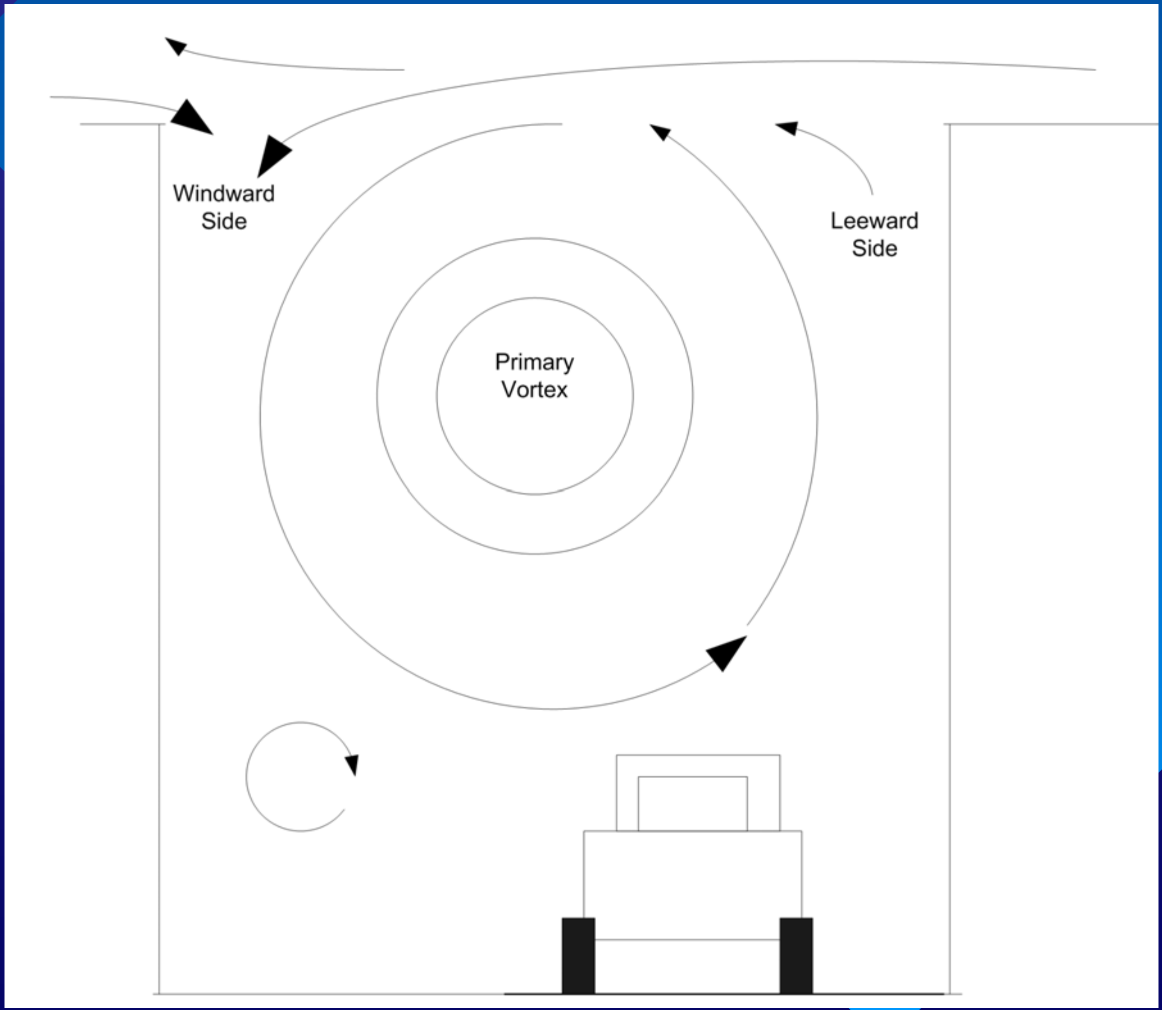
Roadway (Microscale) Modeling

- Interface of multiple areas:
  - Transportation Infrastructure
  - Vehicle Travel Patterns
  - Emission Factors/Fates
  - Meteorology

Roadways: Embedded in the Real World



Complex Microscale Phenomena in “Urban Canyons”



Approaches to Modeling

- Simplifications of complex meteorology
  - Computational fluid dynamics
  - Lagrangian puff model
  - Gaussian models with near-roadway assumptions

Guidance on Dispersion Modeling

- EPA transportation conformity regulations require hot-spot analysis of CO and PM_{10} for federally-funded projects
  - $PM_{2.5}$, CO, and PM_{10} options under review
- "*Guideline for Modeling Carbon Monoxide from Roadway Intersection*"
  - http://www.epa.gov/scram001/tt25.htm#guidance
  - Requires use of CAL3QHC
- No current guidance for air toxics

Modeling Air Toxics

- Microscale air quality models needed to estimate facility-specific impacts
- Examples:
  - Freeway construction
  - New travel patterns due to road closing
  - NEPA

The Gaussian Models

- CALINE3
  - EPA-approved model for transportation impacts along roadways
- CAL3QHC
  - EPA-approved model for intersection modeling, with traffic queues, idling, stop/go cycles
- CALINE4
  - Modified CALINE with some intersection options

Example: CALINE4

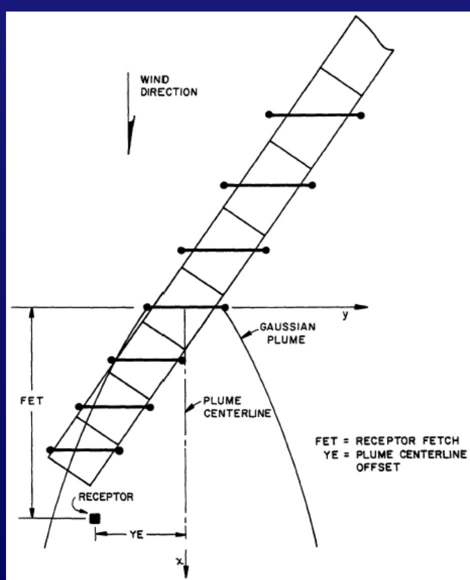
- CALINE4 is one of the CAL series of roadway dispersion models
- Developed by California DOT (CalTrans)
- Like other CAL models, employs continuous Gaussian plume algorithm
- Modifications for vehicle-induced mechanical and thermal turbulence

Basic Theory in CALINE4

- CALINE4 uses Gaussian plume model for "line sources"

$$dC = \frac{q\,dy}{2\pi u \sigma_y \sigma_z}\left[\exp\left(\frac{-y^2}{2\sigma_y^2}\right)\right]\left\{\exp\left[\frac{-(z-H)^2}{2\sigma_z^2}\right] + \exp\left[\frac{-(z+H)^2}{2\sigma_z^2}\right]\right\},$$

where dC = Incremental Concentration
q = Lineal Source Strength
u = Wind Speed
H = Source Height
σ_y, σ_z = Horizontal and Vertical Dispersion Parameters.



ELEMENT SERIES REPRESENTED BY SERIES OF EQUIVALENT FINITE LINE SOURCES

- Dispersion algorithm adjusted to account for vehicle turbulence near roadways

Simplifications in CALINE

- "Mixing Zone"
  - Volume above and 3 m out from edge of traffic lanes (at a minimum)
  - Accounts for air mixing in traffic, Gaussian dispersion curves used outside zone
  - Cannot reliably predict concentrations within this zone

What you need to run CALINE4

- Roadway geometry
  - Width, length (by segment), height, flat/bridge/fill
- Traffic patterns
  - Hourly traffic on links (observed or modeled)
- Emission factors
  - Based on MOBILE6.2
- Meteorology
  - Wind speed, angle, and standard deviation of angle

The Next Generation (?)

- HYROAD (Hybrid Intersection and Road Air Dispersion Model)
  - Developed by National Cooperative Highway Research Program under ICF Consulting
  - Combines advanced traffic algorithm, Gaussian and Lagrangian air quality models to handle calms better

Other Resources

- Tutorials
  – http://legacy.eos.ncsu.edu/eos/info/ce400_info/www2/cal3qhc.html
- CalTrans Air Quality Web Site
  – http://www.dot.ca.gov/hq/env/air/index.htm
- Commercial front-end packages are available for these models
- OTAQ Air Toxics Center
  – Chad Bailey - bailey.chad@epa.gov